# NORTH RIVER FLOOD PLAIN MANAGEMENT STUDY

## Colrain, Massachusetts

United States Department of Agriculture

SOIL CONSERVATION SERVICE
Amherst, Massachusetts
in cooperation with

Massachusetts Division of Water Resources
Franklin Conservation District
Town of Colrain, Massachusetts

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# INTRODUCTION

This report presents the results of a flood plain management study of the North River located in Colrain, Massachusetts.

The Soil Conservation Service (SCS) of the U.S. Department of Agriculture assists state agencies and local communities in the development, revision, and implementation of their flood plain management programs by carrying out cooperative flood plain management studies in accordance with Federal Level Recommendation 3 of "A Unified National Program for Flood Plain Management" and Section 6 of Public Law 83-566 which addresses principles contained in Executive Order 11988, Flood Plain Management. Flood plain management studies also support national conservation objectives (reduction of upstream flood damages) included in the Resource Conservation Act.

The Division of Water Resources of the Massachusetts Department of Environmental Management acts as liaison between local, state, and federal agencies with respect to overall flood plain information activities. The Division establishes priorities for flood plain management studies and assists state and local levels to encourage the use of the developed flood plain information as a tool for wise flood plain management.

The town of Colrain requested technical assistance on a flood plain management study on the North River with the following objectives:

1. Develop alternatives to reduce damage from flooding, sedimentation, and streambank erosion.

2. Evaluate the effects of existing erosion problems if no action is taken and the effects of corrective action if alternatives are implemented.

These local study objectives meet national and state flood plain objectives as outlined in the Joint Coordination Agreement for Flood Plain Management Studies between the Soil Conservation Service and the Massachusetts Water Resources Commission.

This flood plain management study report describes flooding, streambank erosion, and sedimentation problems along the North River. At each problem area the effects on the surrounding area are described if no action is taken and also if alternatives are implemented. The town of Colrain will use the study to correct existing problems and develop a river management plan for normal stream maintenance.

The Massachusetts Division of Water Resources coordinated study inputs with other state agencies; specifically, the Massachusetts Division of Fisheries and Wildlife and the Massachusetts Department of Environmental Protection. The U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory in Hanover, New Hampshire was contacted for information on ice jams along the North River. The Federal Emergency Management Agency provided hydrologic and hydraulic data which were developed for the Flood Insurance Study on the North River. The town of Colrain identified the problem areas along the North River, provided information, and coordinated the study with the residents.

## STUDY AREA DESCRIPTION

The North River Watershed is located in northern Massachusetts and southern Vermont and is within Hydrologic Unit Number 01080203-060. (See Figure 1, Location Map, for the general location of the watershed.) At the USGS stream gauge near the confluence of the North River and Deerfield River in Shattuckville, the North River has a drainage area of 88.4 square miles.

The study area for the flood plain management study is comprised of the flood plains of the North River, the East Branch of the North River, and the West Branch of the North River within the town of Colrain, Massachusetts. About 15 miles of stream reach are included in the study limits.

The East Branch of the North River originates at Ryder Pond in Whitingham, Vermont, and flows in a southerly direction until it joins the Deerfield River in Shelburne and Charlemont. Foundry Brook originates in the hills of the northern section of Colrain and flows in the southerly direction until it joins the East Branch. Taylor Brook has its headwaters in the town of Heath and flows in an easterly direction until it joins the West Branch of the North River. The West Branch originates in Whitingham, Vermont and flows in a southwesterly direction through Heath to join the East Branch in Colrain.

The topography of Colrain is of glacial origin. Lying among the foothills of the Green Mountains, Colrain is hilly with many hilltop elevations reaching 1,700 feet. The soils in Colrain are predominantly of the Westminster-Colrain-Buckland Associations with rolling to steep slopes and rocky, moderately acidic, shallow to bedrock soils. Also included in this Association are deep nonstony to extremely stony, well-drained and moderately well-drained loamy soils with some hardpan. In the level to gently sloping terrain of the terraces and flood plains, the soils are well-drained, strongly acidic, sandy and gravelly.

The climate of the region is moderate in temperature and precipitation. Average temperatures range from 70 degrees Fahrenheit (F) in the summer to 23 degrees F in the winter. The average annual precipitation is 47 inches.

The town of Colrain, a community of 43.2 square miles in north-central Franklin County, is located in western Massachusetts, 45 miles north of Springfield. The 1980 population of Colrain was 1552 (Federal Census), giving a population density of 36 persons per square mile. During the decade 1970-1980, the population of Colrain increased by 132 people or approximately 9 percent. The 1985 population (State Census) has increased to 1595 people.

Colrain is an agricultural and manufacturing community. General farming and dairying are among the principal agricultural pursuits. Manufacturing consists of textiles finishers and production of wood products. The American Fiber and Finishing Company is the major employer in the community, and they manufacture a variety of fabric products including medical gauze supplies. Most of the plants are located along the North River in the villages that comprise Colrain.


**Figure 1**
**LOCATION MAP**

**FLOOD PLAIN MANAGEMENT STUDY**
**North River, Massachusetts**

The upland slopes within the North River Watershed are predominantly forests. Flatter terrain along the North River valley floor is largely agricultural.

Development in the watershed has occurred primarily within the flood plain of the river in Colrain. Residential and industrial development is located in Colrain center and the small villages of Lyonsville, Griswoldville, and Shattuckville. There are approximately 15 residences and three industrial buildings located within the flood plain area.

Major flooding has occurred on the North River, the East Branch of the North River, the West Branch of the North River in 1869, 1878, 1936, 1938, 1955, and 1987. These floods swept away dams and small buildings and washed out roads and bridges. In the past several years, flooding caused by ice jams has occurred on the East Branch. Foundry Brook has caused minor local flooding in the low-lying area near its confluence with the East Branch of the North River.

The USGS stream gauge at Shattuckville (No. 01169000) has recorded discharges on the North River since 1940. The flood of record since the gage has been in operation is the April 5, 1987 flood, which had a discharge of 15,300 cubic feet per second and an approximate return period of 60 years (which means this discharge can be expected to be equalled or exceeded on the average of once in 60 years).

There are no flood control structures in Colrain or on any of the streams flowing through Colrain. However, nonstructural measures for flood protection are being utilized to aid in the prevention of future flood damages. These are in the form of land use regulations which control building within areas that have a high risk of flooding.

## STUDY FINDINGS

### Land Use Analysis

The land use in the town and along the rivers was analyzed using 1972 land use information. A river corridor was delineated by a strip of land on each side of the river extending 1,000 feet from the river centerline. The analysis included the three main river reaches in Colrain: the East Branch, the West Branch, and the main stem of the North River. The land use within the river corridor was updated to 1988 by a visual field examination.

Table 1 compares the 1972 land use for the town to that within the river corridor. Over 75 percent of the town is forested and approximately 15 percent of the land in the town is used for agriculture. Urbanization accounts for less than 2 percent of the land in the town. About 75 percent of the urban land and nearly one-third of the agricultural land in the town is located in the delineated river corridor. This confirms that most of the urban and agricultural activity is located along the river system.

TABLE 1

1972 LAND USE 1/

| Land Use | Area in Town (Ac.) | Area in Corridor (Ac.) | Corridor Percent of Town (%) |
|---|---|---|---|
| Agricultural | 4,009 | 1,161 | 29.0 |
| Urban | 396 | 292 | 73.7 |
| Forest | 21,428 | 1,625 | 7.6 |
| Water | 142 | 98 | 69.0 |
| Other* | 1,689 | 193 | 11.4 |
| Total | 27,664 | 3,369 | 12.2 |

*Other land use includes gravel pits and abandoned fields.

1/ The 1972 Land Use was obtained from the publication by William P. MacConnell, Remote Sensing 20 Years in Franklin County, Massachusetts 1952-1972, Bulletin No. 626, Massachusetts Agricultural Experiment Station, University of Massachusetts at Amherst, MA, May 1975 or from 1972 Land Use and Vegetation Cover Map produced by the Massachusetts Map Down Project directed by William P. MacConnell.

From 1972 to 1988 approximately 15 percent of the agricultural land in the river corridor was converted to urban land, forest, and abandoned fields. During this period the urban land increased over 20 percent. Table 2 summarizes the land use changes which have occurred in the river corridor. The 100-year flood plain covers an area of approximately 600 acres along these rivers and makes up about 18 percent of the river corridor. Even though most of the urban land in the town falls within the river corridor, very little of this land is within the 100-year flood plain. The land use within the 100-year flood plain is mainly agricultural and abandoned fields. The town of Colrain has effectively maintained compatible land use in the flood plain with its existing regulations and should continue the same approach by keeping any urban development above the 100-year flood plain level. As part of its zoning laws the town has established a Flood Plain District which is based on the Flood Insurance Study and Maps dated July 1980.

TABLE 2

RIVER CORRIDOR LAND USE CHANGES

| Land Use | 1972 1/ Acreage | 1988 Acreage | Difference | Percent Change (%) |
|---|---|---|---|---|
| Agricultural | 1,161 | 979 | -182 | -15.7 |
| Urban | 292 | 354 | + 62 | +21.2 |
| Forest | 1,625 | 1,647 | + 22 | + 1.4 |
| Water | 98 | 98 | 0 | 0.0 |
| Other* | 193 | 291 | + 98 | +50.8 |

*Other land use includes gravel pits and abandoned fields.

1/ The 1972 Land Use was obtained from the publication by William P. MacConnell, Remote Sensing 20 Years in Franklin County, Massachusetts 1952-1972, Bulletin No. 626, Massachusetts Agricultural Experiment Station, University of Massachusetts at Amherst, MA, May 1975 or from 1972 Land Use and Vegetation Cover Map produced by the Massachusetts Map Down Project directed by William P. MacConnell.

## River Erosion

The North River is a high gradient river and has a high volume bedload movement. Erosion is particularly severe along meander bends. The East Branch of the river runs through deposits of outwash sand and gravel throughout its entire length in Massachusetts. The West Branch runs through glacial outwash for about the lower two-thirds of its length. The upper third of the West Branch flows on glacial till as does Taylor Brook, one of its main tributaries. The glacial outwash consists of a coarse-grained sand and gravel with about 5 to 15 percent silt. The outwash can erode easily when undercut along steep banks. Flood flows along undercut meander bends take away about 4 feet (perpendicular to the stream) of land annually. In

the areas of glacial till, erosion takes place by slumping or slope failure into the stream where the water acts to wash out a high percentage of fines. At times of high flow, this type of erosion contributes to a substantial suspended sediment load in Taylor Brook and the West Branch of the North River.

Bedload movement in the watershed is significant. A detailed study of bedload was not undertaken, but a field review shows large accumulations downstream of bridges where channel velocity drops. Bedload of gravel and cobbles has been transported and filled in behind the Kendall dam and the small dam on the West Branch. The smaller dam has lost its storage capacity because it has filled to the crest of its weir with sediment.

Both bank and channel bed erosion appear to have been accelerated by a change in the stream gradient. This may have been caused by a concrete mill dam, upstream of Foundryville, failing during the 1936 flood. The concrete dam appears to have stored a significant amount of sediment during its life, judging by the amounts of gravel remaining behind the breached dam along the banks. The dam acted as a sediment trap for its life until it breached. After it breached, the river began to readjust to the new gradient and is continuing to adjust to this new level today. The flood of April 1987 also had an effect on the watershed causing extensive erosion of the streambanks. Emergency restoration work was done to protect some streambanks from erosion and to remove sediment accumulation in the channel to provide capacity. The river continues to adjust to the effects of this streambank and channel restoration.

Rivers are part of a dynamic system. When there is a change in the physical characteristics of the river, the river system will respond to the changes to approach equilibrium. Changes in streamflow or sediment load can cause the river to respond with changes in the erosion rate or sediment deposition along the river system. Some examples of this process are as follows:

1. An increase in streamflow (increased runoff due to development) will result in an increase in erosion of the streambanks and channel. This will further result in an increase in sediment load and downstream deposition.

2. If intensive measures are taken to protect the streambank from erosion (such as rock riprap), the sediment source will be reduced in the reach. This could cause channel erosion within the protected reach, and channel and streambank erosion immediately downstream. Once the eroding stream reaches its carrying capacity for sediment, the sediment will be deposited further downstream.

3. If meandering streams are straightened, the channel slope will become steeper. This will lead to increased erosion of the streambanks and channel within the reach and cause headcutting to develop. Sediment will be deposited downstream. This process occurs in order to reduce the steeper channel slope as the stream approaches equilibrium.

Fisheries

The Massachusetts Division of Fisheries and Wildlife was contacted about the fisheries in the North River. The North River is stocked with trout annually. They have discovered young of the year rainbow trout in the river system which indicates that rainbows are reproducing in the North River. The water quality in the river is excellent and stream conditions provide good cold water fishery habitat. There are significant pools and areas along the stream system which benefit fish habitat. This drainage is a key element in the Connecticut River Atlantic Salmon restoration plan. It will become a major Atlantic Salmon smolt production area in the next 5 to 10 years, when downstream fish passage is installed and the broodstock supply is developed.

The flood and erosion damages from the April 1987 storm destroyed much of the fish habitat along the stream. Emergency restoration measures after the storm made provisions to restore fish habitat areas in the stream by creating pools and ripple areas. The fish habitat has started to come back in the North River.

Sediment removal from the river and installation of streambank protection measures can be a problem during construction. The suspended sediment produced during construction can affect fish habitat. Proper timing of construction and installation of pollution control measures will reduce the amount of sediment in the stream. Additional plantings along streambanks provide a favorable cover for fish habitat.

Problem Areas

The Flood Plain Management Study looked at many problem areas on the North River which were identified by the Town of Colrain. The problem areas represent a range of streambank erosion, sedimentation, and flooding issues. The locations of the ten specific problem areas are shown in Figures 2a and 2b. Erosion problems along Taylor Brook are included as an additional problem area. The town also wanted an evaluation of annual maintenance on agricultural land in the flood plain as a separate problem area.

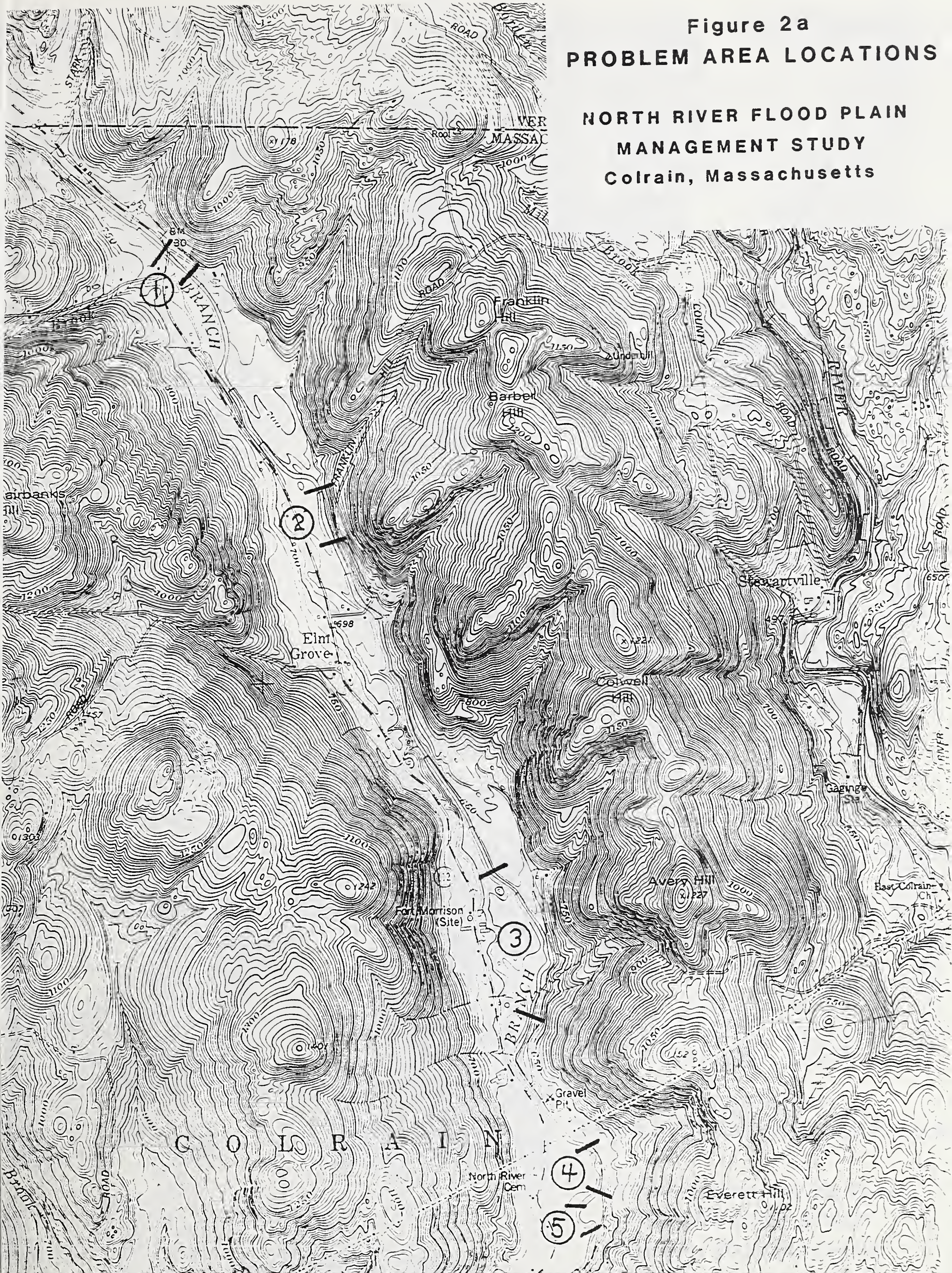
For each of the problem areas, the location and existing conditions are described which include physical, economic, and geologic characteristics. The stream dynamics are also estimated for each site if no action is taken.

The fisheries perspective is very important. The North River currently supports a significant cold water fishery for both hatchery and wild trout. It also will play an increasingly important role in the restoration of Atlantic salmon to the Connecticut River Basin by virtue of the annual planting of several thousand salmon fry.

The fisheries issues and the high cost of rock riprap treatments dictated the recommendations of "soft" treatment alternatives. Even with an economic evaluation based on farmland values at $10,000 per acre, there is a serious cost-benefit ratio concern for these problem areas using a rock riprap alternative. Only in cases where there is a threat to life and/or homes can rock riprap be environmentally and economically justifiable.

# Figure 2a
# PROBLEM AREA LOCATIONS

**NORTH RIVER FLOOD PLAIN MANAGEMENT STUDY**
**Colrain, Massachusetts**



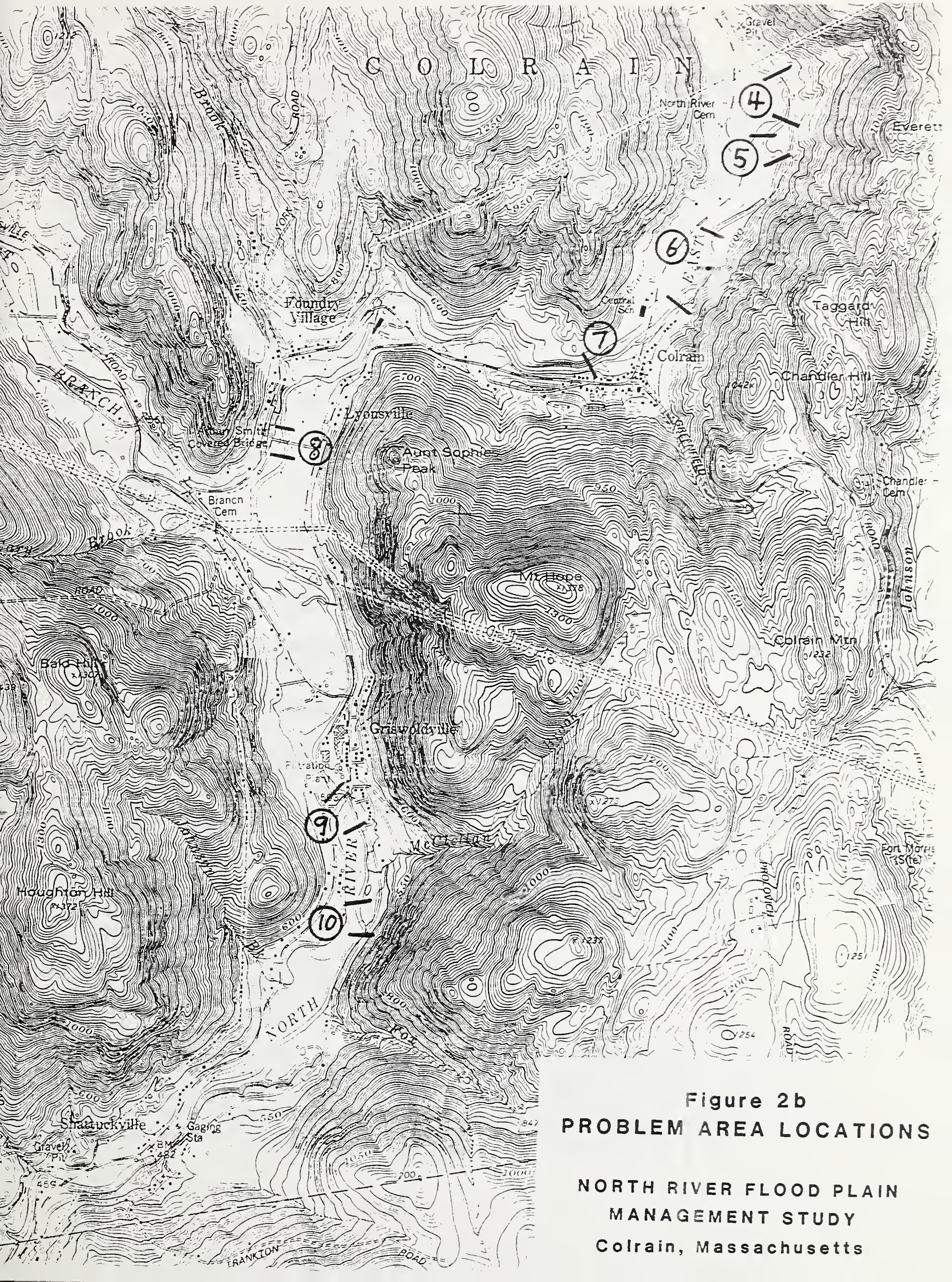



Figure 2b
PROBLEM AREA LOCATIONS

NORTH RIVER FLOOD PLAIN MANAGEMENT STUDY
Colrain, Massachusetts

Additionally, extensive use of rock riprap can cause streambank and channel erosion downstream. Head cutting of the streambed upstream from the channelized areas will further destabilize the river. Implementation of rock riprap measures at the problem areas may lead to more erosion within 10 years and another round of riprapping. If this cycle is repeated, the entire river system will eventually become an artificial channel devoid of fisheries habitat.

The problem areas have been grouped into three categories:

Category I - Streambank erosion and sediment accumulation primarily impacting agricultural land.

Category II - Sediment accumulation diverting streamflows which may impact roadways, structures and/or businesses.

Category III - Unique conditions.

Damages Types

The economic analysis is based on two types of damages occurring in this study area:

1. Land loss due to meander cutting of tilled farmland.

2. The cost of rehabilitating land damage due to overwash left on the cropland, plus sheet and gully erosion on the adjacent cropland.

These problems require reworking by leveling equipment before standard farm equipment (mowing machines, corn choppers) can be used.

Massachusetts Wetlands Regulations

The Commonwealth of Massachusetts has Wetlands Regulations administered by the Department of Environmental Protection. These regulations apply to all areas subject to the jurisdiction of the Wetlands Protection Act (Massachusetts General Laws, Chapter 131, Section 40) designed to protect the following interests:

-protection of public and private water supply
-protection of groundwater supply
-flood control
-storm damage prevention
-prevention of pollution
-protection of land containing shellfish
-protection of fisheries
-protection of wildlife habitat

Alterations and work done in the stream channel of the North River should be evaluated to determine the impact upon the above public interests. For example, if a riparian landowner wants to clear debris from the channel or to widen the channel where it impacts his land, he must submit a notice of intent to the local conservation commission pursuant to the Wetland

Protection Regulations 313 CMR 10.00. The conservation commission will evaluate the impacts that the proposed work may cause upon the protected interests and condition the work accordingly. Work performed for the normal maintenance or improvement of land currently in agricultural use is exempt from the Wetlands Protection Act. If a landowner feels an activity is exempt, he should refer to the recently issued <u>Wetlands Protection Program Policy 90-1: Exemption for Normal Maintenance or Improvement Activity for Land in Agricultural Use</u>. For further guidance on the issue, or to receive a copy of the policy, please contact the Division of Wetlands and Waterways in the Department of Environmental Protection regional office in Springfield.

The importance of determining the applicability of the wetlands regulations to the suggested solutions for problem areas outlined in this report is critical, since some solutions may be readily permitted while others may not be in the public interest under these regulations. In order to get a formal determination as to whether an activity is exempt, project proponents should file a request for a determination of applicability under the regulations (310 CMR 10.05(3)) with the local conservation commission.

Problem Area #1

Gravel bar accumulation below Route 112 bridge.

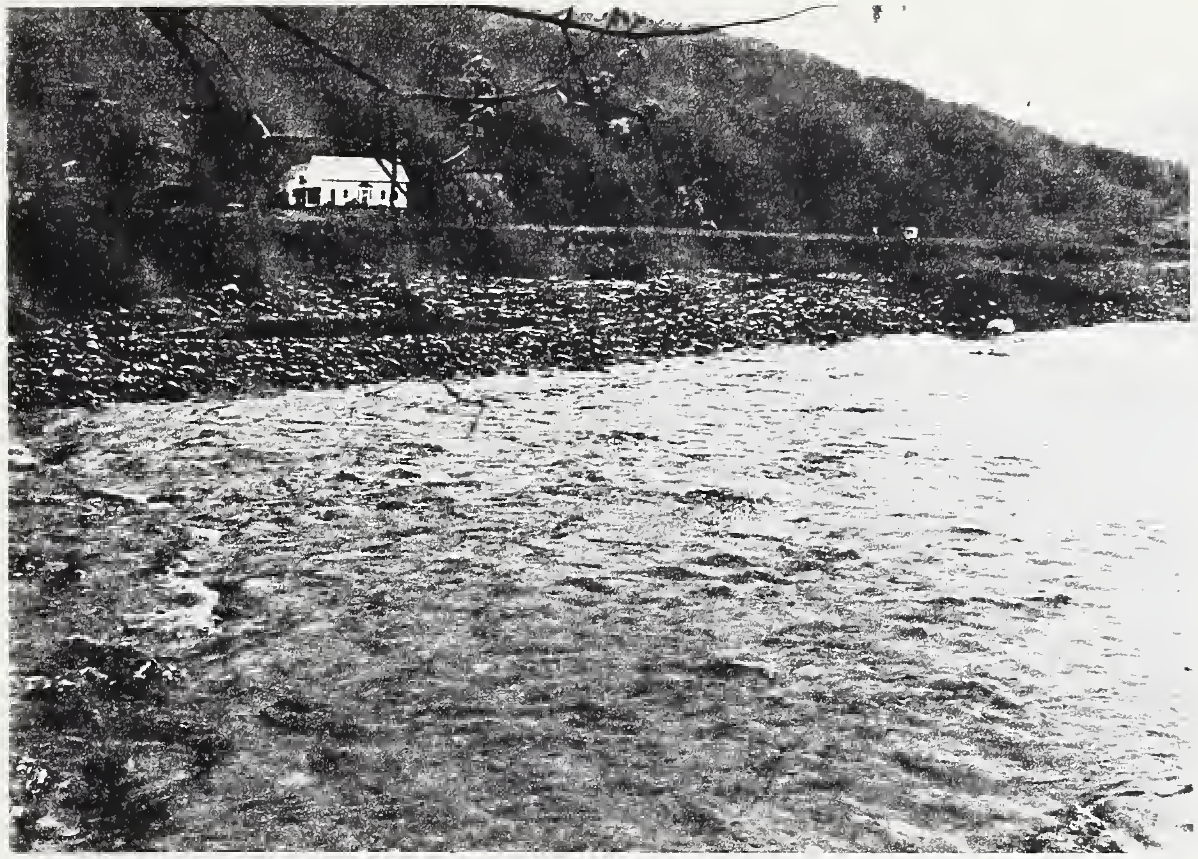
Location: Downstream of the Route 112 bridge near the Vermont state line.

Existing Conditions:

A gravel bar is located downstream of the Route 112 bridge in the center of the channel (approximate size--500 feet long, 40 feet wide, and an average of 2 feet thick). Judging by the size of the trees and brush, the gravel bar has been in place 10 to 15 years. The vegetation has become a trap for the bedload, thus aggravating the sediment accumulation. The stream flows on both sides of the gravel bar and causes erosion of the right bank for 100 feet below the bridge. After the stream channels join together, gravel is deposited along the right side of the stream for a distance of approximately 300 feet downstream. Gravel has not deposited in the channel upstream or underneath the Route 112 bridge. Old bridge abutments are located approximately 50 feet downstream of the Route 112 bridge on both banks. If the old bridge had a pier located in the middle of the stream, any remains of the pier could be the cause of the gravel bar formation.

Under normal runoff conditions the stream flow and sediment balance appears to remain stable. High stream flows could cause further erosion of the right bank and sediment movement. The vegetation on the gravel bar will continue to trap bedload and increase the thickness of the accumulation.

Problem Area #2



Streambank erosion on right bank along hayland.

Location: Approximately 1500 feet upstream of the Franklin Hill Road crossing.

Existing Conditions:

The right bank of the stream has eroded in the form of a meander for a length of 750 feet and a maximum width of 100 feet from the stream edge with an average bank height of 5 feet. Approximately 1.5 acres of hayland already have been lost due to past storms. The hayland soils are classified as prime farmland. Upstream of the eroded area the stream makes a sharp bend, and the water bounces off the bedrock outcrop on the left side of the stream into the right eroded bank.

Based on the farmland values in the town, the economic loss in this problem area amounts to $1,000 annually of cropland lost to meander cutting. The infertile overwash and leveling of gullies costs $200 per year in land restoration work. Total cost of erosion at this site is $1,200 annually.

Stream degradation will continue with the right bank eroding and sediment transported downstream. The stream will try to decrease its channel grade by increasing the meander length. Erosion of the right bank will continue to move into the field and progress downstream. The streambank erosion rate is estimated at 5 to 10 feet per year which results in approximately 1 acre of farmland lost every 10 years.

Problem Area #3

Streambank erosion with gravel deposits graded to protect the bank at the lower end.

Location: Stream reach near the Fort Morrison site on the Colrain USGS Quad.

Existing Conditions:

In this stream reach there is a total of approximately 1100 feet of streambank erosion at three locations and some sediment accumulation. At the upper end of the reach, the right streambank is protected with rock riprap at a bend in the stream. The water deflects off the riprap and erodes the left streambank downstream for a distance of 300 feet with a bank height of 5 feet. Downstream, the right streambank is eroded for a distance of 300 feet with a bank height of 4 feet. The fields adjacent to both banks are used as hayland, with the field on the left bank classified by soils as prime farmland. Further downstream a gravel bar has formed in the stream and water deflects off the rock outcrop on the left side. Further downstream, the right streambank has eroded for a distance of 500 feet with a bank height of 5 feet. Gravel deposits have been regraded to temporarily protect part of the bank in the lower reach.

The land lost from meander cutting throughout this area amounts to approximately another 1/10 of an acre per year. This means the loss of about $1,000 annually in tillable land. Dealing with erosion damages from flood flows and removal of infertile overwash costs these farmers another

$1,000 annually. Total damage for this problem area is about $2,000 per year.

The fields will continue to erode in this reach. Gravel and sediment are being deposited in the lower end of the problem area and contributing toward further erosion on the right bank at the downstream end. Sediment will continue to build up and create additional changes downstream.

Problem Area #4

Streambank erosion along the left bank.

Location: Streambank erosion east of the North River Cemetery.

Existing Conditions:

A large meander has formed, causing the left streambank to erode for a distance of 600 feet with a bank height of approximately 20 feet. According to the landowner and field measurements, the meander has cut 100 feet laterally into the streambank over the past 25 years. The upland was once used for hayland, but has been converted to pasture. The stream flow deflects off the eroded area on the left bank and has caused the right bank to start eroding downstream. The area on the inside of the meander (right side) has grown up with brush and accumulated debris. This restricts the stream flow and directs the river towards the eroded area; thus causing additional erosion of the bank. As the left bank erodes, the right side of the stream accumulates gravel which presently amounts to at least 4,000 cubic yards.

The loss of land here is estimated to be something less than 1/10 of an acre per year, the value of which would be a $1,000 loss of productive land annually.

The stream degradation process will continue with the meander length increasing in order to reduce the channel slope to a more stable grade. The left streambank will continue to erode into the pasture. Sediment will continue to build up on the right side and also be transported downstream. On the area inside the meander, brush will become denser and more debris will accumulate; thus reinforcing the barrier which deflects the stream flow toward the eroded area.

Problem Area #5

Meander streambank erosion and gravel deposits on the right side of the stream.

Location: Streambank erosion southeast of the North River Cemetery (downstream, of Problem Area #4)

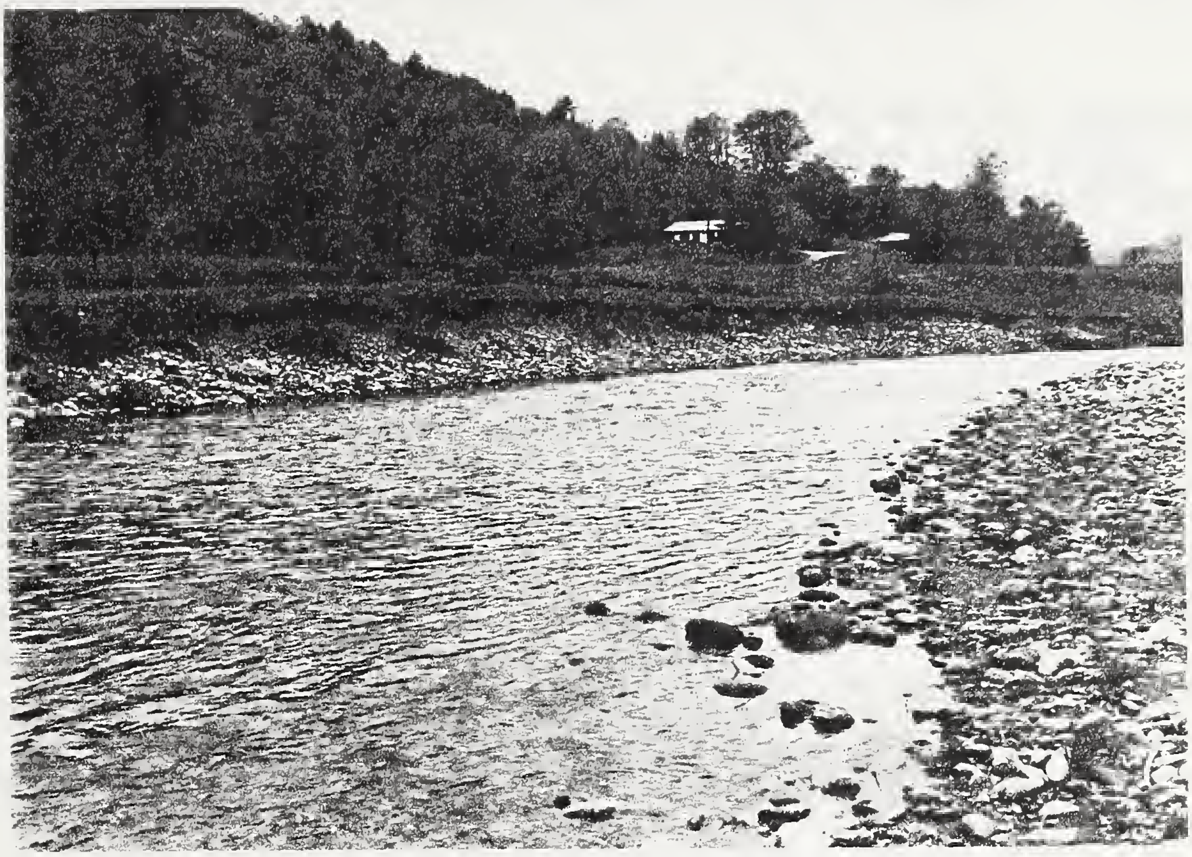
Existing Conditions:

The right streambank has eroded in the form of a meander for a length of approximately 500 feet with a bank height of 4 feet. A large gravel bar has formed inside the meander area and it splits the river flow. The flood plain on the right side is used as hayland and is classified by soils as prime farmland. At the downstream end of the problem area, the stream flow is directed by the meander toward the left bank which is eroding. Approximately 1 acre of agricultural land has been lost on the right side of the stream.

The loss of land due to stream meandering in this problem area may only amount to a value of $500 per year. To rehabilitate the adjacent cropland the cost in terms of labor, machinery, etc. would equate to about $500 annually. Total damage for this reach, therefore, averages $1,000 annually.

Stream degradation will continue with the right streambank eroding and sediment deposited on the inside of the meander. The channel across the inside of the meander will have a tendency to fill in with gravel deposits. The stream system will try to become stable by increasing its meander length. Erosion of the right bank will continue to move into the field and progress downstream with a farmland loss of approximately 1 acre over a 20-year period or an estimated average of 4 feet per year. Downstream of the meander, the deflected streamflow will continue to erode the left bank.

Problem Area #6



Streambank erosion on the right bank upstream of the pumphouse.

Location: Streambank erosion approximately 500 feet upstream of the pumphouse near Central School.

Existing Conditions:

On the right side of the stream, the bank has eroded for a distance of 500 feet and has a height of 6 feet. Rock riprap was installed on the lower 100 feet of the eroded bank to provide protection for a water supply pumphouse, which is currently not in operation but can be used for emergencies. The land along the eroded area is used for hay and is classified by soils as prime farmland.

Approximately 1 acre of agricultural land has been lost due to the erosion since 1970. A gravel bar has formed on the left side of the eroded area. Flood flows are directed towards the pumphouse and have caused some erosion in the field.

This problem area suffers a loss of approximately 1/20 of an acre of cropland per year. The economic loss from this loss of cropland is estimated at $500 annually. If the adjacent farmland was restored, costs are estimated to be $400 annually. The total economic damage in this area is approximately $900 yearly.

The erosion process will continue with gravel deposited on the left side and the right streambank continuing to erode into the hayland. The erosion rate is estimated at 5 feet per year which results in approximately 1 acre of farmland lost every 20 years.

The loss of the pumphouse could occur within 10 years and cost approximately $40,000 to replace. The pumphouse and well are a backup water supply. With changes caused by road construction near the present water supply, the well may become the principal source of water. Discounting the future value of the pumphouse replacement cost and amortizing (8 7/8 interest rate) it over the coming 10-year period amounts to a cost of approximately $2,700 per year.

Problem Area #7

Sediment accumulation under the Route 112 bridge.

Location: Route 112 bridge near Central School

Existing Conditions:

Gravel deposits have accumulated underneath and downstream of the bridge. As a result, some of the streamflow is diverted toward the left abutment on the upstream side of the bridge and is eroding the streambank. Similarly, water is directed toward the right bank on the downstream side and causing erosion. The skewed bridge piers impede the streamflow and cause increased sediment accumulation. According to local officials, up until 1979 the town removed approximately 5,000 cubic yards of gravel deposits each year from this area for use on town roads and material accumulated back by the following year. This operation has been curtailed by state regulations since that period. During the snowmelt period floating ice builds up on the sediment deposits at the bridge and creates an ice jam. Several times ice jams have formed and created a potentially hazardous situation. The inability to remove the sediment has worsened the erosion and ice jam problems.

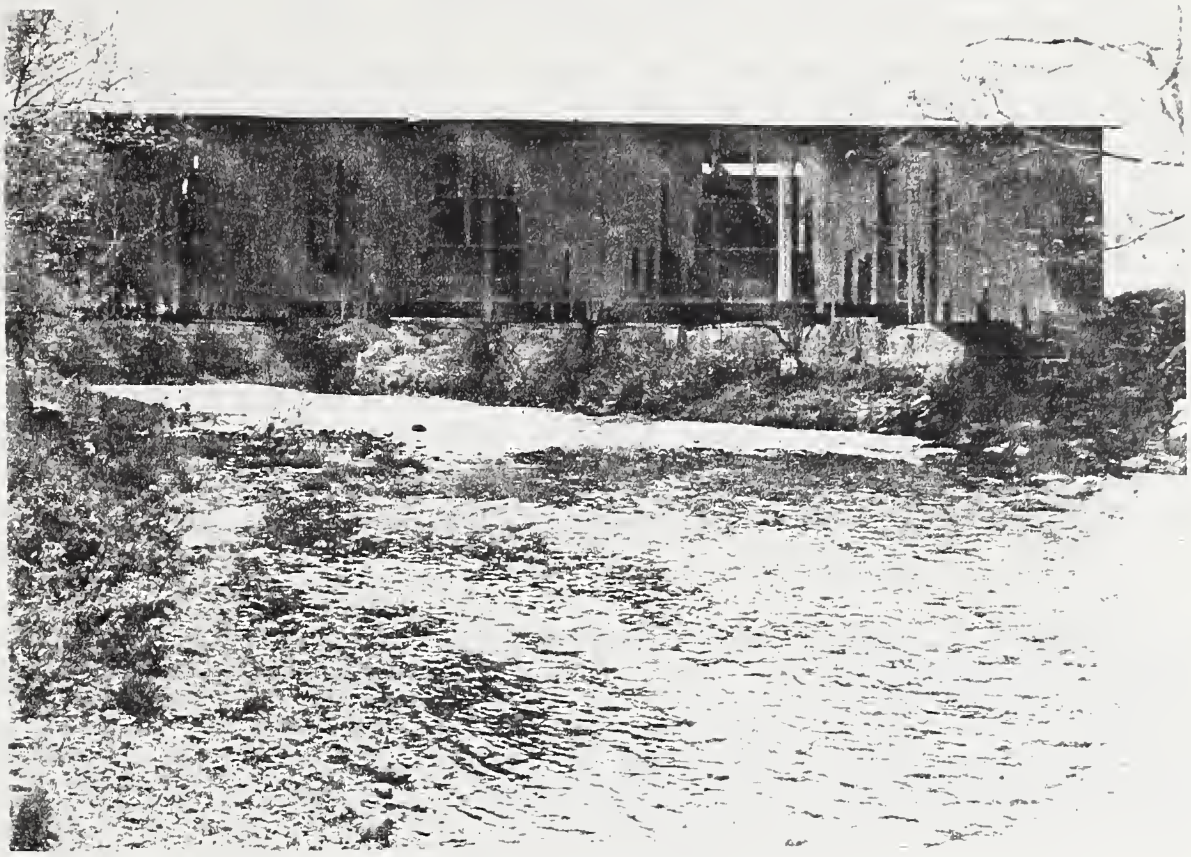
An hydraulic analysis of sediment accumulation was conducted in this problem area. By estimating the normal stream channel grade from surveys and profiles, at least 2 feet of sediment has accumulated under the bridge and a greater amount downstream. This sediment accumulation below the bridge has a hydraulic effect equivalent to approximately 4 feet of material accumulated uniformly across the channel at the Route 112 bridge.

From an economic standpoint, gravel obtained from the stream has a value of approximately $6/cubic yard. The town has been forced to pay $30,000 per year since they can no longer use gravel from the stream. This area of Colrain is also subject to possible property flooding during extreme events. The town garage and two homes would suffer floodwater damages. Average annual flood damages in this area are estimated to be $100 per year.

As part of the stream erosion process, sediment will continue to deposit beneath and downstream from the bridge. The gravel deposits will divert the streamflow and cause additional erosion of the streambanks upstream and downstream of the bridge. Ice jams will form on the sediment deposits more frequently and create potentially hazardous situations. If periodic stream maintenance is not allowed, streamflow will be uncontrolled as it passes through the bridge and the problems will be enhanced.

Currently, River Street becomes flooded during the 100-year frequency storm. As the sediment accumulates to the modeled depth of 4 feet uniformly under the bridge, River Street will become flooded during the 50-year frequency storm. The flooding frequency will approach the 10-year storm for a 6-foot sediment depth under the bridge. Ice jams on these sediment accumulations will increase the flooding frequency.

Problem Area #8



Damaged covered bridge looking upstream.

Location: Arthur Smith Covered Bridge on Lyonsville Road across the East Branch North River

Existing Conditions:

The road on both sides of the covered bridge is lower than the bridge deck; as a result, flood flows go around the bridge across the flood plain. Flooding does not pose much of a problem to the bridge, except during major events. Most of the damages to the covered bridge are caused by ice. The problem originates when ice forms behind the dam. During flood flows the flashboards collapse (as designed) at the dam and the water level is lowered with most of the ice remaining above the dam. The remaining ice traps floating ice as it moves downstream. The ice backs up in the stream channel for a distance well upstream of the covered bridge and jams into the bridge decking. When the ice melts in the channel or the floodwater is suddenly released from the dam, the ice is pulled away from the bridge and causes damage to the bridge deck and sideboards. The covered bridge has a unique wooden arch support structure and has significant historic value. This bridge is now preserved as a historical monument and is not used for traffic. The main value of the bridge is for its social values and links with the historic past of the valley. The town has applied for financial assistance from the state and federal government to repair and preserve the covered bridge, but to date have been unsuccessful. It is listed in the National Register of Historic Places. In September 1990, the town removed the covered bridge from across the river and is beginning restoration.

Recent ice jams have occurred in this area on January 26, 1978; March 6, 1979; and February 20, 1981. Photographs taken during these periods indicate that the flood level and ice came very close to the bottom of the bridge at the time of the picture. Based on the maximum discharge recorded at the downstream USGS stream gauge on these days, the 1981 date recorded the highest discharge at an equivalent storm frequency of approximately 20 years. The other two dates had equivalent storm frequencies less than 10 years. Ice jam damage to the covered bridge consists of shearing off of the bottoms of the upstream sideboards, ripping off of the downstream sideboards, damage to the bridge deck and iron braces.

Floodwaters caused by the ice jams flow across the adjacent farmland and cause severe scouring and have even carried away the blacktop of the road. The cost to correct this land damage by using specialized machinery, labor, etc. and prepare this land for regular farm machinery is estimated to cost $1,000 annually.

Flooding will continue to be a problem when a dam forms at the bridge due to floating debris or ice. Ice will continue to be a problem and may even worsen as sediment accumulates behind the dam and builds up in the channel under the bridge. The ice will continue to damage the covered bridge and eventually cause it to collapse. Maintenance will lengthen the life of the covered bridge.

Problem Area #9

Sediment accumulates downstream from Route 112 bridge.

Location: Route 112 bridge below Kendall in Griswoldville.

Existing Conditions:

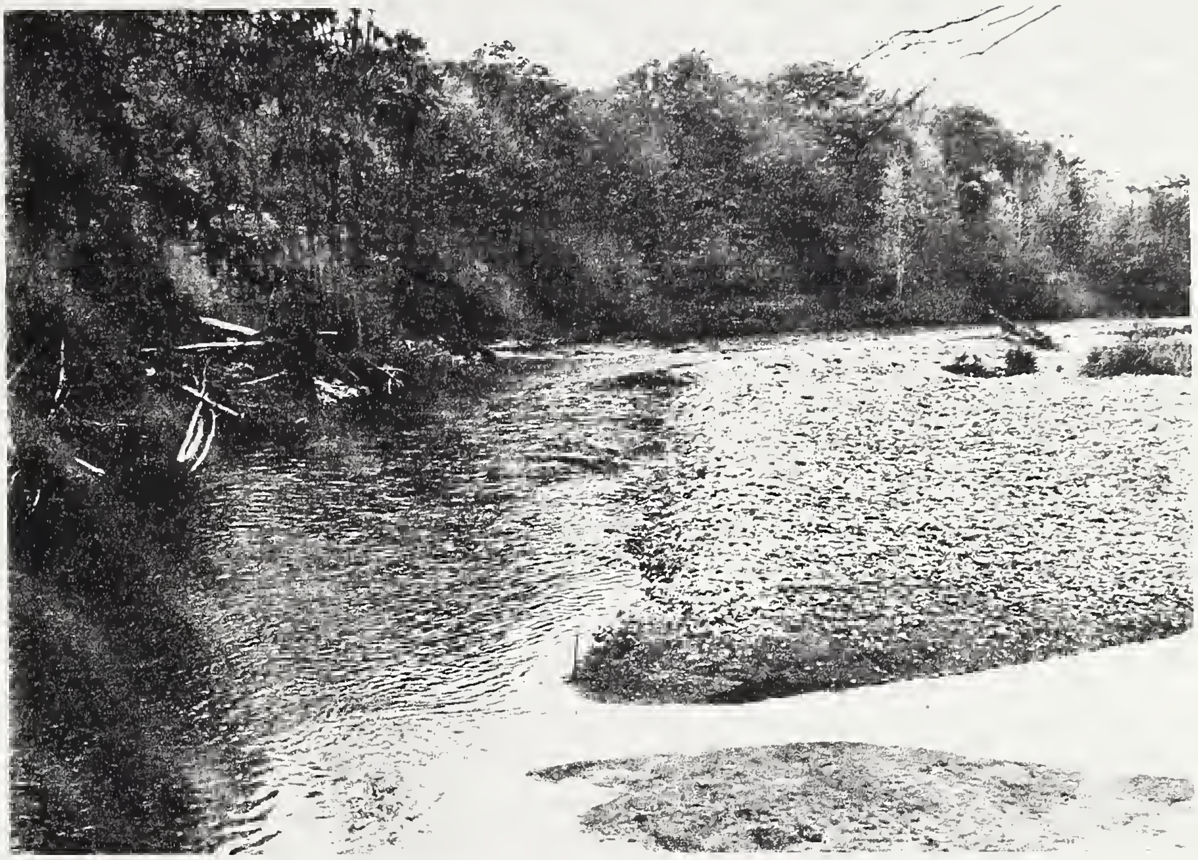
According to the Flood Insurance Study (based on conditions prior to 1987), the 50-year frequency storm overtops Route 112. In the 10 years prior to 1988 approximately 6 feet of sediment have accumulated under the bridge and its capacity has been reduced. Most of the streamflow was directed towards the left side of the channel along Call Road. Sections of the road embankment had eroded and have been protected with rock riprap. After the April 1987 storm approximately 11,500 cubic yards of sediment were removed from the channel to restore the bridge to its original capacity. The hydraulics of the channel were improved so that streamflow is not directed towards the road embankment. With the cleaned out channel Call Road will be flooded during storms greater than the 50-year event. Sediment has started to reaccumulate under and downstream of the Route 112 bridge.

At this problem area four mobile homes are in the flood plain as well as a gas station and two homes on the east side of the river. Under existing conditions average annual damages are estimated to be $7,500 per year.

As part of the stream erosion process, sediment will continue to build up under the bridge and reduce its capacity. As a result, flood flows will inundate Call Road and buildings in the flood plain more frequently. Based

on a hydraulic analysis of sediment accumulation, the flooding frequency of Call Road will approach the 10-year storm for a 6-foot sediment depth under the bridge. The sediment deposits may divert the streamflow which may cause streambank erosion upstream and downstream of the bridge. There is evidence of this occurring in the past, because the downstream left streambank along Call Road has been protected with rock riprap.

Problem Area #10



Gravel bar accumulation looking upstream from Call Road.

Location: Approximately 2,000 feet downstream of the Route 112 bridge in Griswoldville

Existing Conditions:

At a sharp bend in the stream there is a large gravel accumulation in the channel. The stream has cut an overflow channel on the right side at the beginning of the bend. The right bank along the overflow channel is starting to erode for a length of 500 feet with a bank height of 5 feet. Cropland is threatened by the streambank erosion. The bend in the river and the large sediment deposit in the channel are directing the streamflow directly at the left streambank, running along Call Road. The bank along Call Road is protected by rock outcrops along the toe in places and by large boulders.

There is a potential loss of farmland in this area, perhaps as much as 1/20 of an acre per year, possibly translating to an annual land loss cost of $500. The cost of repairing damages to the fields from gullying and infertile overwash is estimated to be an additional $500. Potential total damages in this area are estimated to be $1,000 annually.

As part of the stream erosion process, sediment will continue to accumulate in the stream channel at the bend. During flood flows the overflow channel will enlarge and the right bank will erode into the cropland with an

estimated loss of 1 acre every 20 years. There will be a tendency to form an island between the existing channel and overflow channel. The streamflow will have a direct impact on the Call Road bank and may cause erosion of the left streambank. If the overflow channel becomes the main channel for the stream, there will be less threat of damage to the Call Road streambank and sediment may accumulate along the toe to provide additional protection.

## Problem Area: Taylor Brook

Location: Taylor Brook is a tributary to the West Branch of the North River.

Existing Conditions:

A reconnaissance was made of the eroding areas in the Taylor Brook watershed. Shallow slope failures have occurred along this brook; the most significant are two areas near the powerline crossing. These large shallow slope failures about 150 feet wide have slipped into the brook. The toes of these landslides are being eroded by the brook. The eroded soil is glacial till which contains 30-40 percent silt or fines. The silt creates a significant suspended sediment load during high streamflows. Under these conditions, the American Fiber and Finishing Company, which uses clean water from the river in its processes, cannot use the silt-laden runoff and must suspend or modify their operations.

More slope failures will occur along the steep slopes of Taylor Brook. The exposed slopes will continue to erode, adding sediment to the stream. The brook will wash the sloughed material which will increase the suspended sediment load. This will result in higher water treatment costs for the finishing company and may even close it down. The high silt load in the stream will affect the fish and their habitat.

Problem Area: Flood Plain Agricultural Land

Location: Agricultural land along the East Branch, the West Branch, and the main stem of the North River.

Existing Conditions:

Annual flooding results in deposition of gravel deposits and debris on agricultural fields, erosion of streambanks, and fallen trees and debris in the rivers. The landowners along the rivers want to address these problems to allow maximum utilization and protection of their fields. State Wetland Regulations allow for annual maintenance on agricultural land, but historically the town conservation commission has been reluctant to allow any maintenance due to unclear guidelines. Lack of required annual maintenance is causing a loss of valuable agricultural land.

Gravel and debris will continue to accumulate on the agricultural fields, trees will fall into the rivers and trap debris, and streambanks will continue to erode. Gravel deposits, fallen trees, and accumulated debris create obstructions to divert streamflow which will result in increased streambank erosion. This will create stream meanders which will cut into agricultural fields. Gravel deposits and debris accumulating on the fields will also result in the loss of valuable productive agricultural land. Brush will grow on the abandoned fields and may trap additional debris which would worsen the problem. Flood levels could also increase if large amounts of sediment accumulate in the stream and flood plain.

## STUDY RECOMMENDATIONS

This report was nearly completed when the April 1987 floods occurred. New problem areas were created and original problem areas were either solved or their situation worsened. Shortly thereafter the "soft" treatment or bio-engineering approach to stream management problems were offered as alternatives.

While this report was being redone to address the changed situation, the bio-engineering approach was also being promoted. Currently there is an EPA grant to fund a demonstration project at several sites on the North River. The EPA grant may demonstrate the use of the bio-engineering approach on as many as six (6) sites.

Recommendation 1. Establish a model bio-engineering effort along an entire reach so that a full range of bank types and river features can be incorporated. The upstream and downstream benefits would be more readily evaluated.

Recommendation 2. The Department of Fisheries Wildlife and Law Enforcement attempts to protect riparian zones and provide access for sportsmen, either by direct purchase or through acquisition of a conservation easement. Fee simple purchase has been the preferred method since it allows the agency a full range of land management options. The width of the strip purchased varies with the terrain, and the habitat requirements of the resource. Depending on the site, it is assumed the North River could be protected by a corridor extending about 30 to 100 feet away from the river. This option would allow the farmer to sell a narrow strip of land which is of limited value to the farm operation while continuing to use the rest of the field. The principal negatives associated with this habitat protection method involve cost for survey and the ability to put together an acquisition "package" of streambank property owners. In this case, the corridor would extend from Vermont to at least Colrain center. If negotiators could not option at least 50 percent of the streambank, creation of a functional corridor probably could not be achieved. Under these conditions, the agency would not exercise any of the purchase options.

The other alternative, a conservation easement, secures the right of access to critical fisheries and wildlife habitat along the stream, for protection and management. The landowner keeps all other rights and can use this easement for any purpose consistent with conservation of the habitat. While the width of this zone varies with the habitat and species under management, the Division would probably require a 50-foot easement along each side of the river. There is no minimum percentage of streambank acquisition required, however several contiguous parcels would be sought to initiate the riparian corridor.

Recommendation 3. Conduct a detailed study of the stream aggradation-degradation process for the whole river system. A study of the erosion process in a high gradient stream such as the North River would produce valuable information for analyses of erosion problems and bedload movement in other streams. Ice jams along the river system could also be analyzed.

This study could be tied to a research project at a university or conducted by the Corps of Engineers Cold Regions Research and Engineering Laboratory and the Waterways Experiment Station.

Recommendation 4. The town of Colrain should request assistance from the Franklin Conservation District and the Berkshire-Pioneer RC&D Council to develop a river maintenance plan. This plan would address agricultural maintenance activities which are normally exempt from permit regulations such as:

1. Removal of dead trees, loose debris and gravel deposited on land in agricultural use by a storm event (flood waters or "ice-outs"). These activities do not include the removal of material in streams, land under water, on banks or in a bordering vegetated wetland.

2. Removal of hazardous overhangs. Cutting and removing overhanging trees, which have water damaged and eroded root structures which if not removed may result in stream deflection, increased erosion and a public hazard. This does not include the removal of any tree roots that are attached in any way to a stream bank or land under water.

3. Fence restoration is a normal maintenance activity for land presently in agricultural use provided that the location and type of the fence does not change.

4. Grading and reshaping of land presently and primarily in agricultural use to original grade and condition is an exempt activity provided that:

    a. Material used to regrade and restore the land in agricultural use is the same soil type and composition as the material that previously existed at that location.

    b. In order to stabilize the bank that was restored, disturbed areas are protected with a vegetative cover or natural mulch.

5. Activities not considered normal maintenance, for example, the use of riprap and culverts.

Individuals are encouraged to file a Request for a Determination of Applicability with the local conservation commission to avoid the risk of enforcement action where the status of the work regarding agricultural maintenance exemption may not be clear.

Recommendation 5. The town should continue to control land use along the river through local and state flood plain and wetland regulations. Also, due to high mobility of the North River bedload and resulting sedimentation, and the reduced capacity of bridges to allow for maximum discharge of waters below them, the 100-year flood elevations in the Colrain Flood Insurance Study may be too low. This could place those structures identified as being in the 100-year flood plain in greater risk of flooding than the study indicates, depending upon the amount of sediment accumulated near bridges.

The town should request the Franklin Conservation District and the Division of Water Resources to develop alternatives for specific retrofitting and floodproofing for the structures identified as being in the 100-year flood plain (Problem Areas 7 and 9).

<u>Recommendation 6</u>. Problems Areas 1, 2, 3, 4, 5 and 6 are grouped into Category I; streambank erosion and sediment accumulations primarily impacting agricultural land. Some "soft" treatment or bio-engineering alternatives are:

- -Anchored trees
- -Bank sloping with armored toe
- -Deflectors
- -Bank sloping with brush mat and armored toe

Individuals may request assistance from the Franklin Conservation District to develop a specific design for their needs. Each alternative also has its unique set of operation and maintenance requirements.

However, spot treatment of problem areas which usually only transfers the problem within the reach, should be avoided unless necessary for immediate protection. Assessing and treating an entire stream reach is usually more efficient and effective.

## A. Installation

### 1. Anchored Tree Revetment

The use of trees cut near the site of a streambank protection job will often provide satisfactory bank protection when properly installed. This type of revetment work requires considerable labor and the use of equipment for cutting the trees and moving them into proper position along the bank. The life of the measure depends upon the type of trees used and the effectiveness of vegetation established on the bank. See Figure 3, which illustrates an acceptable method of installation. Use trees with a trunk diameter of 12 inches and above. The type of equipment available to move trees into place will limit overall size of trees that can be used. This method usually can be accomplished with available farm equipment.

Trees have a limited life and must be replaced periodically. In streams where heavy ice flows occur, considerable damage may be done to the trees. Loss of trees through damage or deterioration will again expose the bank to the current which will continue to undercut and erode the bank unless revetment is repaired.

The stability of the bank above the normal water level can be increased by planting trees and shrubs. Planting should be delayed until the trees have silted in and deposits formed in back of them. The rapidity with which silting occurs in the revetted area depends on the amount of sediment transported by the streams.

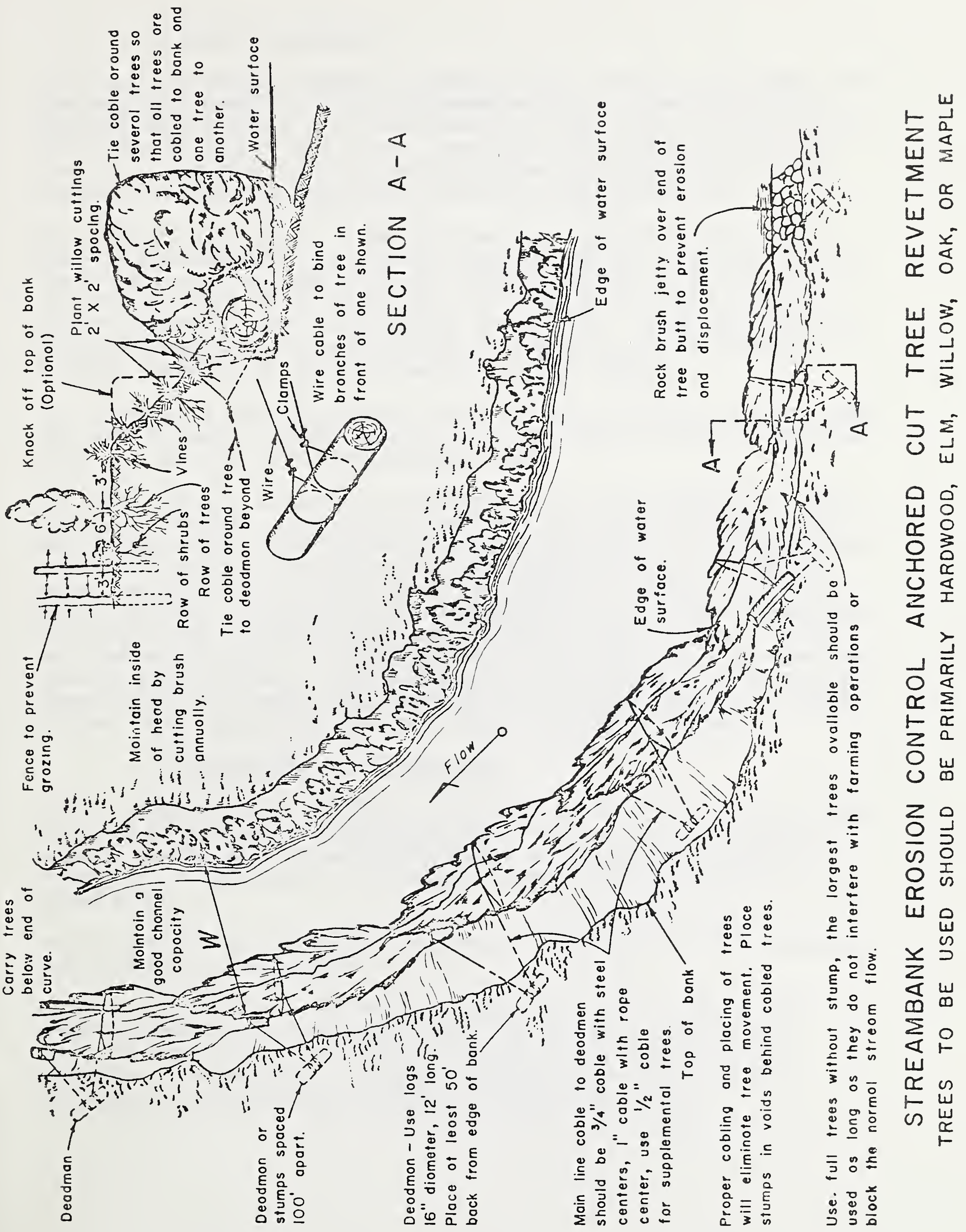

Carry trees below end of curve.
Deadman
Fence to prevent grozing.
Knock off top of bonk (Optionol)
Plant willow cuttings 2' X 2' spocing.
Tie coble oround severol trees so that oll trees ore cobled to bank ond one tree to another.
Mointain a good chonnel copocity
W
Mointain inside of head by cutting brush annuolly.
3'
6'
3'
Row of shrubs
Row of trees
Vines
Tie coble oround tree to deodmon beyond
Water surfoce
Wire
Clamps
Wire cable to bind bronches of tree in front of one shown.
Deodmon or stumps spaced 100' apart.
SECTION A-A
Deodmon - Use logs 16" diometer, 12' long. Place ot leost 50' back from edge of bank.
Flow
Main line coble to deodmen should be 3/4" coble with steel centers, 1" cable with rope center, use 1/2" coble for supplemental trees.
Top of bank
Edge of water surface.
Edge of water surfoce
Rock brush jetty over end of tree butt to prevent erosion ond displocement.
A
A
Proper cobling and placing of trees will eliminote tree movement. Ploce stumps in voids behind cobled trees.
Use. full trees without stump, the lorgest trees ovalloble should be used os long os they do not interfere with farming operations or block the normol streom flow.
STREAMBANK EROSION CONTROL ANCHORED CUT TREE REVETMENT
TREES TO BE USED SHOULD BE PRIMARILY HARDWOOD, ELM, WILLOW, OAK, OR MAPLE

Figure 3

## 2. Brush Mat Revetment

Brush mats with shrub plantings, protected at the toe with rock riprap, will give very good results. This is an expensive type of construction due to the hand labor involved. As a brush mat has a short life, its main value is to afford a mulch that will permit a dense growth of vegetation to take over. It is practical only at locations where willow brush and rock are available in quantities sufficient to meet the need of the job.

The construction procedure is to place the rock toe first, using it as a base for the brush mat. The rock toe should be carried to the low point of the channel and be at least 18 inches thick to remove the danger of displacement during flood flows. It is not practical to use a rock toe in streams subject to channel scour during flood flows. The reason is that it is seldom feasible to place enough rock to compensate for the downward movement caused by the temporary deepening of the channel.

The sloped banks should be planted before the brush matting is applied. The best time to plant is in the spring. It is difficult to obtain a reasonable stand when planting new cuttings through a mat.

The brush should be placed over the exposed soil as soon as possible after the bank is planted. Bush willow affords the best material and should be laid shingle fashion with the butts pointing up the bank. The brush should be straight enough to lie flat on the bank forming a mat 6 to 18 inches thick, depending on the size of the stream and the ice hazard. The mat is held in place by driving stakes at an angle crossing each other in pairs or by stakes driven straight into the ground about 2 feet 6 inches on center and interlacing with No. 9 galvanized wire. After the wire is attached the stakes are driven deeper, which tightens the wire and binds the mat firmly. Stakes driven at an angle and crossed in pairs are only adaptable to small streams. The details of a brush mat riprap are shown in Figure 4.

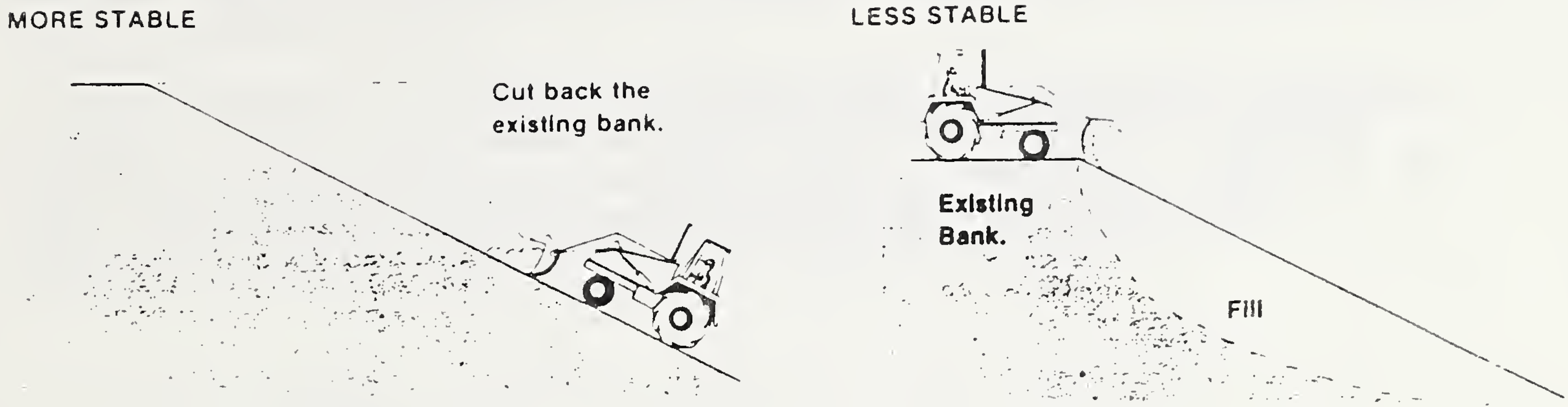
## 3. Bank Sloping with Armored Toe

Erosion often can be controlled by shaping the eroded bank to a more gradual slope and planting grass, shrubs and trees. The part of the bank that is submerged during most of the growing season cannot be protected with vegetation. A rock riprap toe is placed first, using it as a base for the sloped bank.

As with the toe for a brush mat revetment, the rock toe should be carried to the low point of the channel.

A fabric blanket is normally used when vegetation alone cannot provide enough protection, but the erosion is not bad enough to justify more expensive control measures. Since the blanket needs vegetation to be effective, it works best on the upper bank where it is not normally submerged or in streams which are dry for part of the year.

Preferred Method of Creating a 3 to 1 Slope.



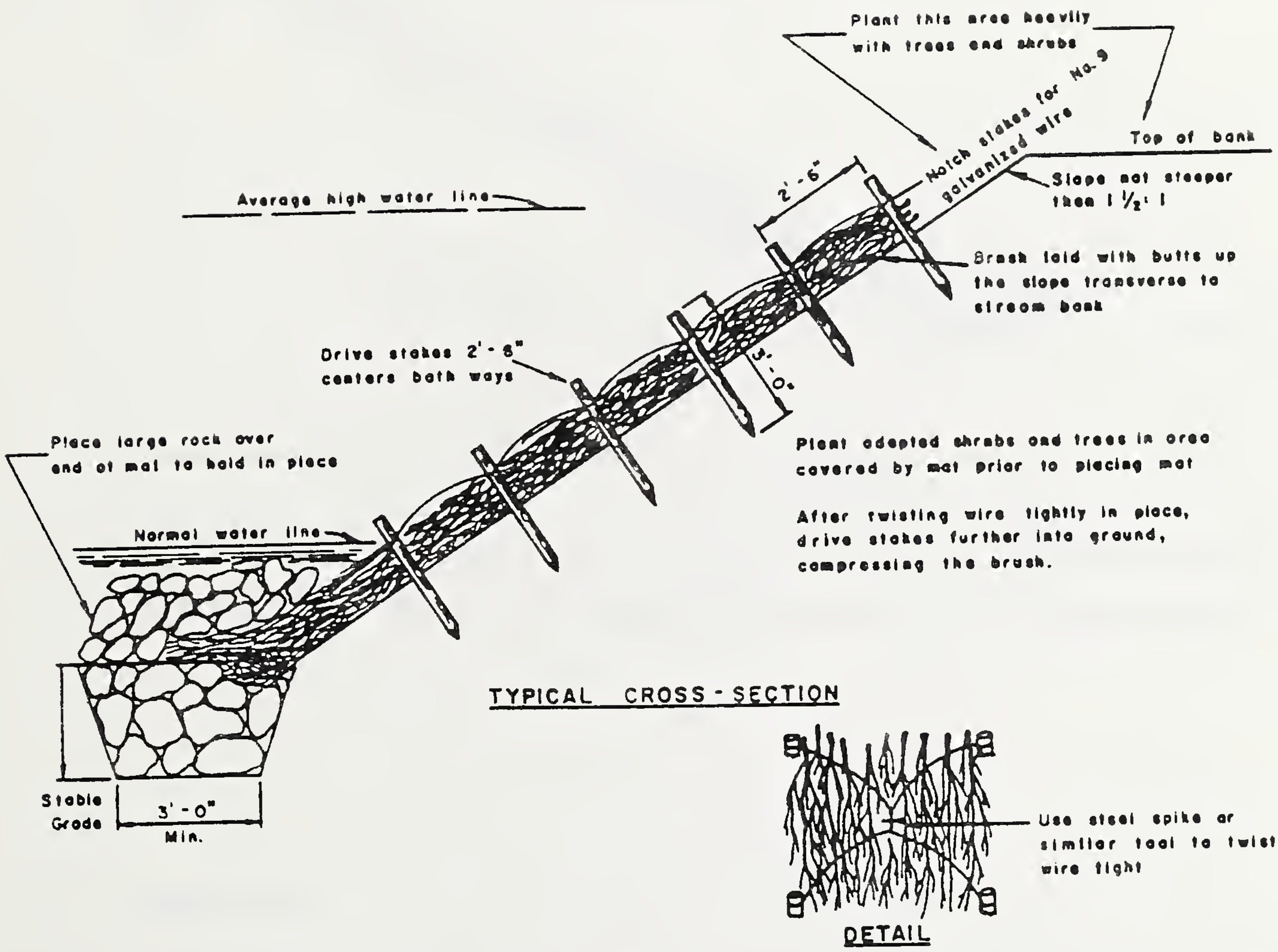




Figure 4. BRUSH MAT REVETMENT

Adapted to small streams having a firm stream bed

The manufacturer of the fabric blanket will provide installation instructions. It can be buried in the face of the bank a few inches, spread on top of the soil, or used as a cover to hold down mulch. In any case, the fabric must be securely anchored in position, usually by staking, and sections should be overlapped 3 to 6 inches. Fabric ends are usually buried in 12-inch deep trenches.

A fabric blanket is a flexible, mesh-like material through which vegetation can grow. It is usually about 1/2-inch thick, and consists of tightly coiled and intertwined fibers of either nylon or excelsior. Initially, the fabric alone protects the streambank and as plants grow, and roots intertwine with the fabric, protection increases (Figure 5).

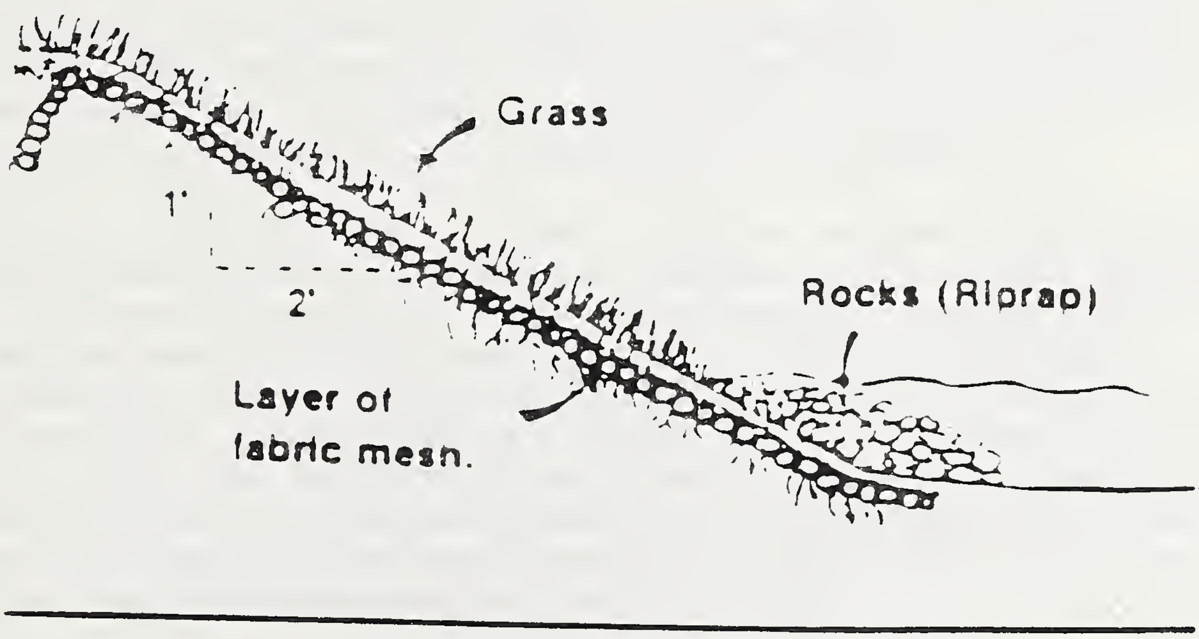



Figure 5 - Cross Section of a Streambank Protected with a Fabric Blanket and Vegetation.

4. <u>Deflectors</u>

Deflectors or jetties are barriers that protrude into the channel to deflect the main force of the current away from the bank. Jetties can be used in series to protect a long section of bank while deflectors allow sediment to accumulate in calmer water.

Deflectors can be solid (rock riprap) or fence-like structures. Since deflectors can greatly influence flow and cause a dramatic change in channel morphometry and velocity in streams, they should be designed by an experienced professional.

B. <u>Maintenance</u>

Continued maintenance of completed streambank control measures is essential to avoid future, and possible greater, streambank damage. In planning for maintenance, it is important to keep the following points in mind:

1. Since it is usually not economical to establish absolutely permanent controls, these measures have a limited life.

2. The nature of maintenance differs in different parts of the drainage area owing to extremes in physical characteristics of rivers and streams.

Because the wandering of currents at flood or high-water stages cannot be determined precisely in advance, the amount and intensity of treatment needed cannot be completely foreseen. Careful examination of plantings and structures during the first few years following installation will disclose points of weakness and which should be strengthened.

<u>Recommendation 7</u>. Problem areas 1, 7 and 9 involve sediment accumulation at bridges and present special engineering problems which require detailed analysis for long-term protection. Models are needed to evaluate the hydraulics and sediment accumulations. There are several structural measures (deflectors, riprap, bridge redesign and alignment) which can be evaluated to see which is the more cost effective and environmentally sound solution. Ice jams should also be evaluated. A grant is needed to fund a research project to develop the model and evaluations. The U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory or a university could probably do the research project.

However, if another flood should occur before these evaluations are completed and/or implemented, it could be necessary to perform emergency work to protect the bridges and public safety.

<u>Recommendation 8</u>. Problem area 8 is a unique condition (Category III) and the town has several options.

Alternative 1 - Raise the covered bridge at least 1 foot. According to the Flood Insurance Study, this would put the low chord of the bridge (bottom of the bridge deck) at the 100-year flood level. Flood damage during the less frequent storms and ice damage to the bridge would be reduced. Costs for raising the bridge would be tied to costs for repair and rehabilitation, and they can be included with any state grant requests. This alternative can be combined with channel excavation for additional protection of the bridge.

Alternative 2 - Relocate the covered bridge to another site which is not endangered by ice or floodwaters. This could be tied to a town historic preservation plan or establishment of a historic district. Relocation costs would be high depending upon the distance that the bridge is moved.

A project for repair, rehabilitation, and relocation of the covered bridge could be submitted to the state for a funding grant.

Alternative 3 - Manage the water level at the dam to reduce the possibility of ice jams. If the water level can be lowered at the dam by removing the flashboards during the ice jam period, the possibility of ice jams may be reduced. The ice blocks would collect at a lower water elevation. An agreement would have to be made with the town of Colrain and the American Fiber and Finishing Company for water management of the dam during flood and ice jam periods. This alternative is only a partial solution and could be combined with other alternatives.

Alternative 4 - Install structural measures upstream of the covered bridge to break up and control the floating ice. This will reduce the backup of ice in the stream channel and damage to the bridge. Specific structural measures should be based on recommendations by the Corps of Engineers Cold Regions Research and Engineering Laboratory. It may be possible to have a demonstration project of structural measures in conjunction with a state grant for preserving the covered bridge. The Resource Conservation and Development Coordinator can assist the town with coordinating a demonstration project.

<u>Recommendation 9</u>. The Taylor Brook problem is also a unique condition (Category III). Since the stream has a high gradient and steep side slopes, conventional engineering practices will be very costly to install. Bio-engineering plantings may work on the steep slope in combination with limited drainage to remove the water and rock riprap protection at the toe. Access to the sites is going to be very difficult and construction costs will probably still be high. This area is very steep and may be very difficult to control with any type of measure.

One consideration would be to establish a demonstration project to evaluate the effectiveness of bio-engineering plantings at a few sites. A special grant could be sought for this purpose. However, further investigation concerning the actual cost to the American Fiber and Finishing Company to filter out the suspended silt should be pursued before any significant public funds should be expended for upstream treatment.

<u>General Recommendations</u>. On projects involving public land or have a public benefit, the town can seek funding from the Massachusetts Division of Waterways.

Also, the town can request assistance from the Franklin Conservation District and the Berkshire-Pioneer RC&D Council to seek grants and coordinate assistance to the town.

Problem Area 10 does not warrant any action now. Even applying low level "soft" treatment techniques will disturb more area than stabilize. If the bank erosion worsens and removes all the woody vegetation, techniques outlined for Category I problems could be applied.

It is important to understand that the erosion process is a natural one. Although it is generally a slow process, it represents the normal situation on the North River. Because of this, attempts to control streambank erosion should be recognized as a continuous, rather than a one-time effort. The construction work is just the beginning. The complete project will require regular maintenance.

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